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**REPORTED MODALITY PREFERENCES OF SONAR OPERATORS**

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### Summary

One hundred forty-four sonar operators, 78 submarine (STS) and 66 surface (STG), completed a survey which questioned them in the areas of preferred work schedule, general modality preference, and modality preference for sonar operation. A majority of subjects reported being most alert and efficient between 8 a.m. and noon. STS operators had a strong preference for a 6 on/12 off work schedule. Responses to general modality questions indicated a preference for the visual modality, which was similar in proportion for both STS and STG groups. On questions pertinent to sonar operation, most operators indicated a visual preference. However, on two of these items, proportionally more STS than STG operators showed an auditory preference. Interestingly, 99% of all the subjects reported that present sonar systems are biased toward visual information. Yet, this survey showed that only 57% of the sonar operators rely on or feel they are better at utilizing visual information. The implications of individual operator differences and modality preferences as they relate to sonar task performance are discussed.

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## Introduction

Recent advances in technology have provided a wide range of visual displays for sonar operation. These enhancements have led some engineers to suggest that the use of sound signal processing on future sonar systems will no longer be required. However, much of the recent literature indicates that sonar performance is enhanced when information is presented bimodally (Lewandowski & Kobus, 1989).

A modern sonar task requires the processing of information from multiple sources regardless of whether the information in a given modality is task relevant or not. Due to the many possible stimulus situations, some investigators have tried to determine the optimal method of presenting auditory and visual information in a sonar task (Halpern & Lantz, 1974; Kobus et al., 1986; Lewandowski & Kobus, 1989). Whereas a number of studies have investigated how bimodal information may facilitate or detract from performance, these findings are based on group performances; consequently, little is known about individual differences of operators. For example, none of the sonar simulation studies reported on the modality preference of subjects. People who engage in bimodal processing tasks, such as sonarmen, may have preferences for visual or auditory processing that may influence their overall performance (and how they go about performing the task). It may provide an additional enhancement to overall task performance if engineers were able to incorporate operator preference into the design of future systems. For example, an operator who prefers auditory input might be able to adjust the equipment in such a way as to highlight this input.

It is important to determine what modality preferences trained sonar operators have, and how these may carry over into operational performance. Therefore, a preliminary research study on the self-reported modality preferences of a large sample of experienced sonar operators was conducted. We decided to examine modality preference in relation to sonar operation, as well as "general" modality preferences. A questionnaire was designed to assess modality preferences of both submarine and surface sonar operators.

## Method

### Subjects

Subjects were recruited through the Fleet Sonar School in San Diego. One-hundred and forty-four experienced sonar operators participated, 66 surface (STG) and 78 submarine (STS) operators. The two groups were comparable in age, years of sonar experience, and sea duty. The mean age of the subjects was 28.3 yrs. (range = 19-42 yrs.). The mean length of experience was 7.6 yrs. (range = 1-22 yrs.). The mean time at sea was 4.5 yrs. (range = 1-13 yrs.). Subjects ranged in rate from E-3 to E-8. Twenty-five (17.4%) subjects reported a slight hearing loss since they started their sonar career, and four (2.8%) subjects reported a slight visual defect that was uncorrectable. Twenty-three (16%) subjects reported that they had corrected vision.

### Measure

A questionnaire was devised for the study comprised of seven descriptive items, two work preference items, and 12 items related to auditory and visual modality preferences. Of the 12 modality questions, five pertained to general modality preference, whereas the seven additional questions were specifically related to sonar performance (see Appendix 1). The items were ordered in blocks beginning with the descriptive, work preference, general preference, and then the sonar items. The response positions were alternated to avoid response sets. After completion, all responses were scored -1 for a choice indicating an auditory preference, and +1 for a choice indicating a visual preference. Summary scores were determined for the general preference questions (General) and sonar preference questions (Sonar) by summing the values across each block of questions. A negative overall score indicated an auditory modality preference, and a positive score indicated a visual modality preference.

The reliability and validity of such a novel instrument must be considered. Since reporting was done privately and anonymously, there is high confidence the respondents were honest, and social desirability or forms of bias did not play a role in responses. As a check on internal consistency, each block of questions (General & Sonar) had a pair of similar questions (General, Q2 & Q5; Sonar, Q9 & Q10). Internal consistency coefficients on these pairs of questions were .60 and .78 for

General and Sonar questions respectively. Retest reliabilities were computed on a subsample of 12 subjects (who completed the survey four months earlier) and ranged across items from .65 to .90. Lower retest reliability was found on the General items. It appears from these modest data that the General preference portion of the survey has questionable reliability and would need to be interpreted with caution. The reliability of the Sonar items, however, seemed adequate for such an exploratory study.

### Procedure

Questionnaire items were developed, piloted, and modified per feedback. The resulting questionnaire (see Appendix 1) was then distributed to sonar operators working at Fleet Sonar School. All subjects were recruited by a senior manager at the school. Return rate was 90%. Subjects were asked to complete the questionnaire privately. The questionnaire was self explanatory and easy for the operator to complete. Completion of the questionnaire took between five and 10 minutes. Questionnaires were returned to the department manager who collected them and forwarded them to the experimenters.

### Results

The frequency distributions for responses of STG and STS operators to questions on work and modality preference are reported in Tables 1-3 below. Table 1 shows the results of responses to two questions concerning work cycle. The question about which period of the day operators are "most alert and efficient" was answered similarly by both groups. The most often selected time period was 8-12 in the morning (55.6%), followed by the noon to 4 p.m. period (18.1%). The question on the preferred work schedule elicited quite different responses from the two groups of subjects. STG operators had no clear preference, with 34.8% selecting the 4 on/8 off, 28.8% the 6 on/12 off, and 25.8% the 8 on/16 off schedules. STS operators, on the other hand, preferred the 6 on/12 off schedule as an overwhelming first choice (73.1%).

Table 1. Frequency distribution of each group's responses to work preference questions.

<u>Variable</u>	<u>Responses</u>	<u>Total</u>	<u>%</u>	<u>STG Freq.</u>	<u>%</u>	<u>STS Freq.</u>	<u>%</u>
"Times most alert"	00-04	2	1.4	1	1.5	1	1.3
	04-08	9	6.3	2	3.0	7	9.0
	08-12	80	55.6	38	57.6	42	53.9
	12-16	26	18.1	14	21.2	12	15.4
	16-20	15	10.4	6	9.1	9	11.5
	20-24	8	5.6	4	6.1	4	5.1
	missing	4	2.8	1	1.5	3	3.9

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	on/off <sup>1</sup>						
"work schedule"	6/12	76	52.8	19	28.8	57	73.1
	12/12	5	3.5	5	7.6	0	0.0
	8/16	31	21.5	17	25.8	14	17.9
	4/8	30	20.8	23	34.8	7	9.0
	6/6	2	1.4	2	3.0	0	0.0

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<sup>1</sup> The first number indicates the number of hours on watch. The second number denotes the number of hours off watch.

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Table 2 provides the frequency distributions of responses to the five General modality preference questions. Both STG and STS groups responded similarly on each of these questions. Overall, the responses indicated a general preference in favor of the visual modality, with the exception of question #1 (when relaxing I prefer: music, 83.7%).

Table 2. Frequency distribution of each group's response to General modality preference questions.

<u>Variable</u>	<u>Responses</u>	<u>Total</u>	<u>%</u>	<u>STG Freq.</u>	<u>%</u>	<u>STS Freq.</u>	<u>%</u>
Q1:	Auditory	118	83.7	54	83.1	64	84.2
	Visual	23	16.3	11	16.9	12	15.8
Q2:	Auditory	57	40.1	27	40.9	30	39.5
	Visual	85	59.9	39	59.1	46	60.5
Q3:	Auditory	14	9.8	8	12.1	6	7.7
	Visual	129	90.2	58	87.9	71	91.0
Q4:	Auditory	23	16.0	12	18.2	11	14.1
	Visual	121	84.0	54	81.8	67	85.9
Q5:	Auditory	45	31.9	16	25.0	29	37.7
	Visual	96	68.1	48	75.0	48	62.3

Q1: When relaxing I prefer (listening to music/daydreaming).

Q2: In learning how to use a new gadget I prefer (reading directions on how to use it/being told how to use it).

Q3: My memory is better for (things I've seen/things I've heard).

Q4: I think the more unfortunate handicap is (deafness/blindness).

Q5: In school, I learned better from (the blackboard/an oral lecture).

Table 3 presents the frequency distributions by group for the modality preference questions. Once again operators demonstrated a greater preference for the visual modality. This is consistent across all questions. Questions #9 (What is your best mode in sonar?) and #11 (When tired which do you have a hard time monitoring?) yielded significant group differences in response distributions. For both questions there was a tendency for the STS operators to respond with a proportionally greater preference for the auditory modality than the STG operators. On questions #6, 7, 8, 10, and 12 both groups of operators responded similarly. Of special note is the result of question #12 which indicated that 99% of all operators feel present sonar systems favor visually presented information.

In addition to the frequency data for each separate question, several pairs of questions were cross-tabulated. One cross-tabulation of particular interest involved questions #6 and #7. Of the 49 subjects who said they rely on the auditory mode to make detections, 26 of them also relied on auditory to make classifications; whereas 93 subjects said they

relied on the visual modality for detections, and 55 of these subjects also favored the visual modality for classifications. We also cross-tabulated the sonar preference items with question #9, regarding the "best mode" for sonar operation. It turned out that question #6 shared the most congruence with #9, in that 86% of all subjects selected the same modality as best for detections (#6) and the best overall for sonar (#9). An examination of the various cross-tabulations for the STG and STS groups separately revealed similar distributions on the sonar preference questions.

The next form of analysis involved computation of summary scores based on each block of questions. A General modality preference score was derived by summing values -1 = auditory preference, +1 = visual preference for questions 1 to 5. This General score ranged from -5 to +5. Similarly, a Sonar modality preference score was derived by summing values for questions 6 to 11. The Sonar score ranged from -6 to +6. A Total modality preference score was also determined by summing the General and Sonar scores ranging from -11 to +11. The mean scores across all subjects for each summary score were General = +1.37, Sonar = -1.0, and Total = +2.37. The summary scores indicate the general trend toward the visual modality as the preferred modality. Using positive summary score values to denote visual preference, and negative values to denote auditory preference, all subjects were categorized as either having a visual or auditory modality preference. Based on the Total score, 68% of STS subjects and 81.7% of STG subjects showed a visual preference. For the General score 77% of STS and 85% of STG subjects showed a visual preference, and for the Sonar score 47.4% of STS and 65% of STG operators showed a visual preference. Across all of these scores it is evident that more subjects of each group prefer the visual modality. However, whereas only 57% of all subjects showed a visual preference on the Sonar summary score, 99% felt that sonar is predominantly a visual task.

Intercorrelations among the three summary scores indicate that the Sonar ( $r = .88$ ) and General ( $r = .46$ ) scales each correlated significantly with Total score, but did not correlate significantly with one another ( $r = -.002$ ).

Table 3. Frequency distributions of each group's responses to Sonar modality preference questions.

<u>Variable</u>	<u>Response</u>	<u>Total</u>	<u>%</u>	<u>STG</u>	<u>%</u>	<u>STS</u>	<u>%</u>	<u><math>\chi^2</math></u>	<u>p</u>
Q6	Auditory	49	34.5	18	27.7	31	40.3		
	Visual	93	65.5	47	72.3	46	59.7	2.46	.12
Q7	Auditory	64	45.1	30	46.2	34	44.2		
	Visual	78	54.9	35	53.8	43	55.8	.06	.81
Q8	Auditory	61	42.4	29	43.9	32	41.0		
	Visual	83	57.6	37	56.1	46	59.0	.12	.72
Q9	Auditory	54	37.5	18	27.3	36	46.2		
	Visual	90	62.5	48	72.7	42	53.8	5.44	.02
Q10	Auditory	41	28.7	19	28.8	22	28.6		
	Visual	102	71.3	47	71.2	55	71.4	.0001	.98
Q11	Auditory	89	61.8	47	71.2	42	53.8		
	Visual	55	38.2	19	28.8	36	46.2	4.57	.03
Q12	Auditory	5	3.5	4	6.1	1	1.3		
	Visual	138	96.5	62	93.9	76	98.7	NS	NS

Q6: In sonar operation, I rely more on (sight/sound) to make detections.

Q7: I rely more on (sight/sound) to make classifications.

Q8: When fatigue sets in, I find myself more likely to notice changes in (visual/auditory) information.

Q9: My best mode in sonar performance is (visual/auditory).

Q10: Given a choice of target information in only one modality, I would choose (visual/auditory).

Q11: When I am tired I have a hard time monitoring the (headphones/visual display).

Q12: Present sonar systems cause operators to favor (visual/auditory) information.

## Discussion

The purpose of this study was to examine the reported preferences of sonar operators in regard to work schedule, general modality preference, and modality preference for sonar signal processing. Hundreds of military-supported studies have investigated auditory and/or visual processing, and many of these have been focused on operators (i.e., sonar, radar). However, none has asked the operator which modality he prefers for certain functions. Since research has shown that sonar performance can be enhanced by presenting concurrent redundant auditory and visual signals (Colquhoun, 1975; Lewandowski & Kobus, 1989, 1990), and since this research indicated that operators often rely on one modality over another, it seemed useful to investigate further the modality preferences of sonar operators. Also, given the nature of STG and STS selection, training, and functioning, it seemed important to examine for group differences in modality preference. Additionally, there was an attempt to measure the construct of "General" modality preference and determine if it had any relationship to modality preference in sonar operation.

It should be noted that the survey and its results must be considered with caution. The survey was designed specifically for this study and it does not meet all the requirements of a highly reliable and valid instrument. Nonetheless, a survey such as this one can be a valuable exploratory tool that leads to further specific research. In this light we will discuss the results of this study.

The results regarding work schedule are fairly straightforward. Both groups of operators felt that they were most alert and efficient in the morning (8 a.m. to noon) followed in frequency by the afternoon period (noon to 4 p.m.) and the early evening period (4 p.m. to 8 p.m.). These results are similar to reported changes in cognitive performance throughout the day (see Boff & Lincoln for a review, 1988). Only a handful of operators preferred the late evening or early morning work periods. In terms of preferred work schedule, the groups differed in their responses. STS operators predominantly favored the 6 on/12 off schedule followed in popularity by the 8 on/16 off schedule. This result is probably driven by the experience of the submarine operators who normally utilize a 6 on/12

off work-rest cycle. By contrast, the most often selected schedule by the STG operators was the 4 on/8 off schedule followed by the 6 on/12 off and the 8 on/16 off schedules.

Of most interest in this study are the responses to the Sonar modality preference questions (see Table 2). Despite the fact that 99% of the subjects view present sonar systems as predominantly visual in operation, a sizable proportion of operators (i.e., 37.5% for question #9) seem to prefer the auditory modality or rely on it more in sonar operation. Likewise, in bimodal performance tasks there are times when operators, at least some of them, perform better in the auditory (versus visual) modality (see Kobus & Lewandowski, 1986). This presents a dilemma for those designing sonar systems, and consequently the operator who may have a preference and a strong capability in the auditory modality. This dilemma also has implications for the training of sonar operators, chiefly, determining how the trainee best derives information to make detections and classifications. At present, it seems that individual operator characteristics such as modality preference and skill are not systematically considered in sonar design, training, or operation. This research, albeit preliminary, suggests that operator modality preferences and strengths should be more intensively studied. Human factors research suggests that the design of the machine should take into account the characteristics of the operator. In addition to modality preference, these authors believe that other individual characteristics merit research attention as well (i.e., cognitive abilities, attention allocation, stress reactivity, etc.).

The results of the General modality preference questions do not merit much discussion. On the encouraging side, the results suggest a strong general preference for the visual modality, even more than what is reflected in the sonar preference questions. Perhaps this captures what many already accept as true, that vision is the dominant sense. This may offer some external validity for the results from this survey. However, one cannot overlook the fact that question #1 may be a leading question, inherently biased toward an auditory response; that the internal and retest reliabilities are low; and that there is yet no empirical evidence for a construct (or a measure) such as "General modality preference". Some have tried to measure general learning and thinking styles with limited success

(e.g., Torrance et. al., 1977), and others have shown modality preferences in certain learning tasks (i.e., reading; see Boder, 1973), yet no one has been able to delineate a general modality preference across tasks. It may be that intra-individual variation opposes the nature of a general modality preference. Rather, a given individual may prefer or rely upon a mode of information based on the demand characteristics of the task more than any inherent propensity. This question still needs to be resolved, and this study does little to clarify such a broad theoretical issue. It is still feasible, however, that the assessment of a general modality preference will tell us something about how potential sonar operators will approach their job and succeed at it.

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## APPENDIX I

### SONAR MODALITY PREFERENCE QUESTIONNAIRE

Instructions: Please take 10 - 15 minutes to complete this questionnaire (all items) and return to \_\_\_\_\_. PLEASE DO NOT LEAVE ANY BLANKS.

#### BACKGROUND:

Initials \_\_\_\_\_ Age \_\_\_\_\_  
Years of sonar experience \_\_\_\_\_ Approximate time at sea \_\_\_\_\_  
Rate \_\_\_\_\_ Submarine or surface \_\_\_\_\_  
Types of sonar systems used \_\_\_\_\_

Describe visual and/or hearing problems in the past 10 years.

#### WORK PREFERENCES:

What 4 hour period of the day are you usually most alert and efficient?  
(check one)

<input type="checkbox"/> 12-4 a.m.	<input type="checkbox"/> 12-4 p.m.
<input type="checkbox"/> 4-8 a.m.	<input type="checkbox"/> 4-8 p.m.
<input type="checkbox"/> 8-12 a.m.	<input type="checkbox"/> 8-12 p.m.

What would be your first preference for a Work-Rest schedule for sonar?

<input type="checkbox"/> 6 on/12 off	<input type="checkbox"/> 4 on/8 off
<input type="checkbox"/> 12 on/12 off	<input type="checkbox"/> 6 on/6 off
<input type="checkbox"/> 8 on/16 off	<input type="checkbox"/> 8 on/8 off

PLEASE CIRCLE ONE ANSWER TO EACH QUESTION BELOW:

#### GENERAL PREFERENCES:

1. When relaxing I prefer \_\_\_\_\_.
  - a. listening to music
  - b. daydreaming
2. In learning how to use a new gadget I prefer \_\_\_\_\_.
  - a. reading directions on how to use it
  - b. being told how to use it

3. My memory is better for \_\_\_\_\_.  
a. things I've seen  
b. things I've heard
4. I think the more unfortunate handicap is \_\_\_\_\_.  
a. deafness  
b. blindness
5. In school, I learned better from \_\_\_\_\_.  
a. the blackboard  
b. an oral lecture

SONAR PREFERENCES:

6. In sonar operation, I rely more on \_\_\_\_\_ to make detections.  
a. sight  
b. sound
7. I rely more on \_\_\_\_\_ to make classifications.  
a. sound  
b. sight
8. When fatigue sets in, I find myself more likely to notice changes in \_\_\_\_\_ information.  
a. visual  
b. auditory
9. My best mode in sonar performance is \_\_\_\_\_.  
a. auditory  
b. visual
10. Given a choice of target information in only one modality, I would choose \_\_\_\_\_.  
a. visual  
b. auditory
11. When I am tired I have a hard time monitoring the \_\_\_\_\_.  
a. headphones  
b. visual display
12. Present sonar systems cause operators to favor \_\_\_\_\_ information.  
a. visual  
b. auditory

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